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THE SUGAR BEET IN GERMANY, WITH SPECIAL ATTENTION TO ITS RELATION TO CLIMATE *

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To What Extent Does Climate Influence the Sugar Beet Crop? A positive or negative answer cannot be given to this question, although evidence seemingly leading in one direction or the other is available. The period of observation and study is much too short to give absolutely conclusive results. In fact, most of the quantitative observations cover such brief and disconnected periods that almost any sort of conclusion seems at first hazardous. Still, from the few statistics at hand, coupled with the experiences as related by a number of men who have devoted most of their lives to sugar beet growing or some other phase of the industry, an effort to ascertain a little evidence that may at least lead to something definite is worth while.

Figure 8† presents a general survey of the relation of production, temperature, rainfall and area planted. The temperature and rainfall curves, it should be noted, represent the averages for the *growing months,* April to September inclusive. Breslau and Magdeburg, as previously stated, constitute the centers of the two areas of principal production. Inasmuch as these stations do not differ markedly in latitude, altitude or even sufficiently in longitude to cause any decided difference in the broad climatic characteristics, it has been considered permissible to combine them and thereby empirically approach perhaps something of a generalization for the entire sugar beet zone.

Regardless of all other factors which might be mentioned that could have caused or helped cause the fluctuations in the production curve, it must be admitted that these variations are strikingly similar to those in the rainfall curve (Fig. 8A and C). A seeming relation to temperature is also visible, though not so convincing. A detailed analysis follows.

For those years in which there occurred a considerable change in area planted no comparisons will be attempted. In 1898 the rainfall and temperature both increase and the production decreases. In 1904, with no very marked rise in temperature but a decrease in precipitation, production again decreases. In 1911 with a decided rise in temperature and an even more marked fall in precipitation, the crop decreases, despite an increase in area planted. In 1903, with an increase in temperature and rainfall or a return to what might seem normal, judging from the curve as a whole, the crop increases. In 1905, with temperature stationary and an increase in rainfall, an amount equal to its decrease during the preceding year, the crop increases. Exactly what is the balance between rainfall and temperature that will effect a normal crop or an exceptional crop? There seems to be an optimum lurking here somewhere. What it is cannot be stated.

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* Concluded from pp. 241-258, April *Bulletin.*

† On p. 252 of April *Bulletin.*

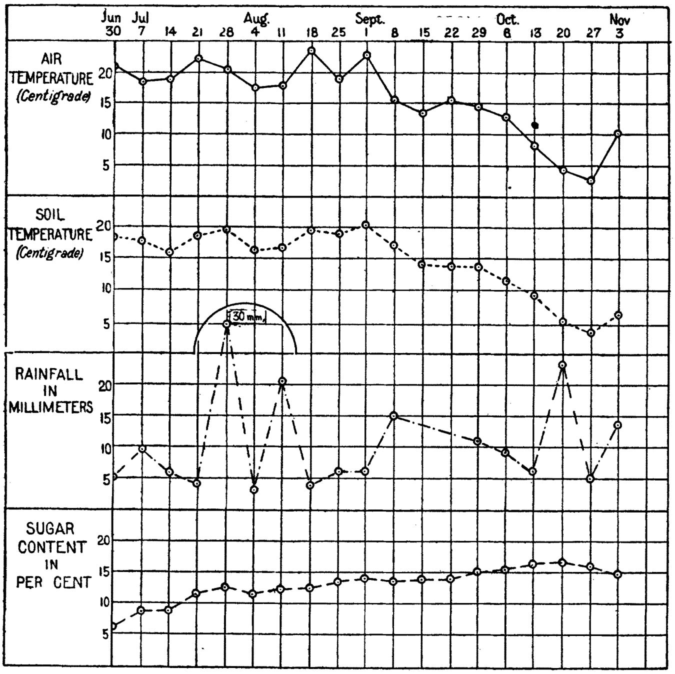

FIG. 15—Curves to show close relation of sugar development in the plant, and weather elements. Curves also indicate relation of soil temperatures and air temperatures.—Ref.: Kuntze, Delitzsch, Germany.

A still closer view of the relation to temperature and rainfall is possible in Figure 15. Although these observations represent only one season they possess suggestions not to be overlooked. The air temperatures and soil temperatures vary uniformly and in the same manner, excepting one or two minor details. In addition, the curve for sugar *content* is introduced. This is of importance, since, as detailed above, it is possible under certain weather conditions to obtain a large production of beets with a *small* sugar content. The general increase in percentage of sugar from June to October is normal. The variations in this increase will be discussed. An analysis follows:

The week from July 7 to 14 represents a decrease in rainfall and soil temperature, but an increase in air temperature; the sugar content remains essentially constant. A rise in temperature, with continued decrease in rainfall, occurs the following week; the sugar content increases decidedly and continues to increase, with a continued rise in the soil temperature, but a fall in air temperature. During the next week, July 28–August 4, the percentage decreases, apparently due to the decrease in air temperature and unusually heavy rainfall of the week previous, or due to decrease in air temperature combined with decrease of rainfall. In the week of August 11-18, with a rise in air and soil temperature and a return of rainfall to what might seem to be a normal amount, the sugar content rises slightly. Proceeding to the next striking variation, September 1-8, the percentage curve falls, while a rapid rise in rainfall accompanied by a sudden drop in temperature occurs. For the week of October 20 essentially similar conditions obtain. Again definite conclusions cannot be drawn. One can only say that the variations in percentage of sugar in the beet and the variations in both temperature and rainfall are suspiciously intimate.

Table II is an attempt to uncover some relationships by empirical means, perhaps not always apparently logical. Breslau and Magdeburg are again employed. The temperature and rainfall for these two chief production centers are given from 1893 to 1912 and compared with the total production of beet sugar in Germany during the same period. Columns 1 to 9 contain the figures, while columns 10 to 16 interpret these figures in terms of increase or decrease over the preceding year by means of algebraic signs. In the averages for temperature and rainfall (columns 1–2 and 5–6, respectively) the periods of growth according to Briem are used as a basis. Sub-column *a* always represents April-May; sub-column *b*, June-July; and sub-column *c*, August-September. Rainfall and temperature figures respectively for each of the two cities are combined in columns 7 and 9 (formed, respectively, by addition of columns 5 and 6 and 3 and 4). In column 8 is given the total beet sugar production of Germany in round numbers. Columns 10, 11,

TABLE II—RELATION OF BEET SUGAR PRODUCTION IN GERMANY TO TEMPERATURE AND RAINFALL, 1893–1912.*

	1			2			3	4	5			6			7	8	9	10	11	12	13			14			15			16			
	BRESLAU Average Temperature C°			MAGDEBURG Average Temperature C°			Avge. Temp. BRESLAU C°.	Avge. Temp. MAGDEBURG C°	BRESLAU Average Rainfall in mm.			MAGDEBURG Average Rainfall in mm.			Rainfall, mm. B + M	Total Production for GERMANY in 1000 tons Ton=1000 kgs.	Temp. C° B + M	Fluctuations in Column 7	Fluctuations in Column 8	Fluctuations in Column 9	BRESLAU Rainfall Fluctuation			MAGDEBURG Rainfall Fluctuation			BRESLAU Temperature Fluctuation			MAGDEBURG Temperature Fluctuation			
	a	*b*	*c*	*a*	*b*	*c*			*a*	*b*	*c*	*a*	*b*	*c*							*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	
1912	14.6	18.9	12.5	10.6	18.4	12.9	15.3	13.9	113.0	126.0	197.0	89.0	98.0	129.0	752.0	**2750**	27.7	+	**+**	−	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**−**	**−**	**−**	**−**	1912
1911	11.5	18.5	18.1	12.6	18.7	18.4	16.0	16.6	87.0	47.0	95.0	28.0	79.0	28.0	364.0	1497	32.6	−	−	+	−	−	−	−	−	−	+	+	+	+	+	+	1911
1910	11.4	18.2	15.0	11.4	17.7	15.2	14.9	14.8	113.7	140.8	208.8	43.0	119.2	171.1	796.6	**2589**	29.7	+	**+**	+	**+**	**−**	**+**	**−**	**−**	**+**	**+**	**+**	**−**	**+**	**+**	**−**	1910
1909	9.8	16.8	16.8	10.4	16.3	15.8	14.5	14.2	101.9	205.9	85.8	55.6	133.4	107.3	689.9	2037	28.7	+	−	−	−	+	−	−	+	+	−	−	+	−	−	+	1909
1908	11.0	18.8	14.5	10.5	18.7	14.6	14.8	14.6	150.0	172.2	110.9	114.1	67.5	71.4	686.1	2079	29.4	−	−	+	+	+	+	+	−	−	−	+	−	−	+	−	1908
1907	11.2	17.1	15.8	11.4	15.6	15.2	14.7	14.1	88.5	113.7	107.7	58.9	227.6	98.9	695.3	2138	28.8	−	−	−	−	+	−	−	+	−	−	−	+	−	−	−	1907
1906	12.8	17.8	15.4	12.3	17.6	15.8	15.3	15.2	127.9	65.9	170.3	97.8	199.6	115.1	776.6	2242	30.5	+	−	+	−	−	+	+	+	+	+	−	−	+	−	○	1906
1905	10.3	19.5	16.5	10.1	19.1	15.8	15.4	15.0	132.2	137.3	105.4	73.5	180.5	108.6	737.5	**2400**	30.4	+	**+**	−	**+**	**+**	**+**	**+**	**+**	**+**	**−**	**+**	**+**	**−**	**+**	**+**	1905
1904	11.1	18.7	16.2	11.7	18.2	15.7	15.3	15.2	72.5	45.0	51.9	60.5	45.9	45.5	321.3	1605	30.5	−	−	+	−	−	−	−	−	−	+	+	○	+	+	+	1904
1903	10.4	17.3	16.2	10.1	17.1	15.6	14.6	14.3	118.2	159.8	112.9	99.3	76.8	128.6	695.6	**1921**	28.9	+	**+**	+	**+**	**+**	**+**	**+**	**−**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	1903
1902	9.0	16.9	14.8	9.1	16.8	14.0	13.6	13.3	74.5	152.4	66 2	69.3	110.9	98.0	571.3	1789	26.9	−	−	−	−	+	−	−	+	−	−	−	−	−	−	−	1902
1901	12.0	19.3	16.0	11.7	18.8	16.2	15.8	15.6	94.2	88.0	128.0	85.9	85.1	107.2	588.4	**2302**	31.4	+	**+**	+	**+**	**−**	**+**	**+**	**−**	**+**	**+**	**+**	**−**	**+**	**+**	**−**	1901
1900	9.9	19.1	17.1	10.2	18.6	16.4	15.4	15.1	68.7	138.4	35.4	69.8	146.3	78.7	537.3	**1979**	30.5	−	**+**	+	**−**	**−**	**−**	**−**	**+**	**−**	**−**	**+**	**+**	**−**	**+**	**+**	1900
1899	10.7	17.1	15.9	10.3	17.3	15.5	14.6	14.4	215.7	157.5	98.1	174.7	126.5	84.9	857.4	**1795**	29.0	−	**+**	−	**+**	**−**	**−**	**+**	**−**	**+**	**−**	**+**	**−**	**−**	**+**	**−**	1899
1898	11.5	16.3	16.6	10.4	15.7	17.2	14.8	14.4	142.1	222.7	140.4	116.8	139.3	38.6	799.9	1722	29.2	+	−	+	+	+	+	+	+	−	+	−	+	+	−	+	1898
1897	10.8	18.4	13.6	10.1	17.7	16.6	14.3	14.8	122.3	201.6	133.6	77.2	114.1	121.2	770.0	**1844**	29.1	−	**+**	+	**−**	**+**	**−**	**+**	**−**	**−**	**+**	**−**	**−**	**+**	**−**	**+**	1897
1896	9.0	19.1	15.5	9.5	18.2	14.9	14.5	14.2	136.9	199.2	164.7	57.2	139.5	128.5	826.0	**1821**	28.7	+	**+**	−	**+**	**+**	**+**	**−**	**+**	**+**	**−**	**−**	**−**	**−**	**+**	**+**	1896
1895	11.9	19.3	17.4	11.9	17.9	11.9	16.2	13.9	55.6	81.3	116.6	63.9	87.2	77.4	482.0	1637	30.1	−	−	+	−	−	+	+	−	−	−	+	+	○	+	−	1895
1894	12.4	17.8	14.6	11.9	17.6	14.2	14.9	14.6	91.6	147.2	106.9	41.5	139.0	140.8	667.0	**1827**	29.5	+	**+**	−	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**−**	**−**	**+**	**−**	**−**	1894
1893	10.7	18.5	15.9	11.6	17.9	16.0	15.0	15.2	63 5	96.2	61.5	21.8	89.0	66.0	398.0	1366	30.2	±	±	±	±	±	±	±	±	±	±	±	±	±	±	±	1893

* *a*=April-May *b*=June-July *c*=August September.

12 correspond respectively to columns 7, 8, 9; columns 13 and 14 to columns 5 and 6; and columns 15 and 16 to columns 1 and 2. The plus sign indicates an increase over the corresponding figure in the preceding year, the minus sign a decrease. For example, the temperature in 1894, column 9, is less than (—) in 1893, in 1895 more than (+) in 1894, and in 1896 less than (—) in 1895, etc. The year 1893 may represent a plus or minus year, since no figures precede; therefore it is representd by both signs. The production figures and the algebraic signs for the year showing an increase over a preceding year are shown in bold-faced type. The observations follow.

Columns 7, 8, 9, and 10, 11, 12: The production in 1893 was exceptionally small considering all of the subsequent years; hence, however slightly improved the conditions might have been in 1894, the production would in all probability show an increase. In the subsequent nine years in which increases occurred an increase in *both* rainfall and temperature appeared four times—namely, in 1901, 1903, 1905 and 1910. In two years, 1896 and 1912, an increase in rainfall and a decrease in temperature are apparent. It is to be noted, however, that these variations occurred after the temperature of the preceding year was exceptionally high and the rainfall unusually low. Further, it is noteworthy that the two years of minimum production—namely, 1893 and 1911—possess essentially the same temperature and rainfall values.

Carrying the analysis to columns 13 to 16, a few more interesting situations appear. During the two years 1894 and 1912, when decided increases in production occurred, the fluctuations in each period were correspondingly similar, excepting in temperature in the second period for Breslau, column 15 *b*, and in the first period for Magdeburg, column 16 *a*. Again, for 1901 and 1910, years of increase and almost equal production, the fluctuations correspond, except in the rainfall for the first period for Magdeburg, 14 *a*. For 1903 and 1905 changes are parallel, excepting for three periods only, namely, in the rainfall in the second period for Magdeburg, column 14 *b*, and in the temperature in the first period for Breslau, column 15 *a*, and in the second period for Magdeburg, column 16 *a*.

If the conditions for the periods of decided decrease in production are sorted out, namely, 1893, 1895, 1904 and 1911, it may be observed that fluctuations with reference to the respective preceding years are identical. Further, the actual figures for these years, columns 7, 8 and 9, show that the combined rainfall for Breslau and Magdeburg is always less than 500 mm, the temperature above 30.0° C. and the production under 1,650,000 tons. An analysis of the figures for the periods reveals a very low rainfall, apparently unusually low, during the second period, never reaching above 100 mm, while the temperature is rather higher, 18.0° C (two instances of 17.9° C).

In concluding the very brief analysis of this tabulation it seems again apparent that there is an optimum for a normal crop, which might be ascertained if observations were extensive enough. At times when one seems to have a hold on something definite the data prove inadequate and the grip slips. There remains but to quote some of the men who have studied this situation, mostly qualitatively, to substantiate, in part at least, some of the above observations.

''It is clear that climate is effective, although just how seems uncertain, for opinions differ. . . . Others fall back on the chemical content of the soil, but this in turn may be shown to be affected by climatic elements.''—Prof. Krüger, Bernburg (12).

''There is an optimum of growth depending on temperature conditions—a minimum which determines the lower limit and a maximum determining the upper limit with a happy medium.''—W. Rimpau (13).

''The quantity of the harvest is unusually influenced by the water supply, in fact much more so than by any other factor that may affect the vegetation.''—Wallny (14).

Extracts from reports on crop conditions in *Die Deutsche Zuckerindustrie,* a weekly journal:—Province of Saxony, ''During the past week measurable quantities of rain did not fall; accordingly the quality of the beets decreased somewhat.''

Western Brunswick: ''The heavy weather during the end of last week, with its 54 mm of rainfall, again soaked the soil, so that the beets showed a considerable increase in weight, but on the other hand an equal decrease in sugar content.''

''The pronounced influence of meteorological elements in many diverse ways is absolutely certain and, further, among other things, is a determining factor in the distribution and concentration of the chemical constituents in the root and in the leaves. . . . Meteorological elements are also quite likely responsible for the so-called *Aufschiessen*—sudden growth of the leaves of the beet. . . .'' (16).—Dr. E. O. von Lippman.

Neither temperature, water nor sunshine alone is more or most important, for conditions may arise where there is sufficient of the one but insufficient or too much of the other. It is true, however, that soils, no matter of what kind, no matter of what chemical composition, will not support vegetation independently of temperature and water conditions, which also have a definite relation to each other. Insolation, wind and relative humidity are also factors to be considered. Inasmuch as these climatic elements seem to determine the development of a profitable sugar beet crop, a crop of national importance, the establishment of a series of observation stations throughout the growing district, combined with a careful study of the observations, should without doubt prove of immense commercial value to all the people.

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